Quantitative Chemical Mass Transfer in Coastal Sediments During Early Diagenesis

Dr. Samuel J. Bentley, Sr.
Coastal Studies Institute and Department of Oceanography and Coastal Sciences
Louisiana State University
Baton Rouge, LA 70803 USA
phone: (225) 578-2954 fax: (225) 578-2520 email: sjb@lsu.edu

Grant Number: N00014-00-1-0768
http://busycon.csi.lsu.edu/bentley/

LONG-TERM GOALS

The objectives of this study are: to measure rates and depths over which macroinvertebrates in selected functional groups transport sediment and create sedimentary structure; and, to derive quantitative mechanistic models for these property distributions. These observations and models will be integrated into mass-transport modeling of dissolved and particulate materials in marine sediments developed under this program. This work is a collaborative effort among Dr. Samuel Bentley (Louisiana State University), Dr. Carla Koretsky (Western Michigan University) and Dr. Yoko Furukawa (Naval Research Laboratory), originally started in 1997 under ONR322GG funding. We will focus on the synthesis of results during this phase. This report summarizes the research activities of Dr. Bentley at LSU.

OBJECTIVES

The specific objectives are:

1. Characterization of changes to sedimentary fabric produced by macrofaunal activity;
2. Millimeter-to-centimeter-scale characterization of sedimentary particle dynamics in laboratory mesocosms and field test sites.
3. Model development to mathematically describe the macrofaunally-induced particle dynamics.

APPROACH

Observations of bioturbation include field measurements of fabric (x-radiography), faunal distribution, and sediment radiotracer distribution, as well as laboratory study of key macrofauna in benthic mesocosms and microcosms.

Bioturbation rate and depth in lab studies has been assessed using a combination of tracer studies and direct measurements. Sediments processed for mesocosm use have spiked with ^{134}Cs to an activity of ~100 dpm/g, and added to unlabeled mesocosm substrate as discrete layers, prior to organism introduction. ^{134}Cs activity is measured by γ-spectroscopy. Non-steady state particle mixing models for both biodiffusive and bioadvective mixing styles (*Hemipholis* and *Schizocardium*, respectively) have been developed in order to evaluate results of benthic microcosm experiments.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Quantitative Chemical Mass Transfer in Coastal Sediments During Early Diagenesis**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Coastal Studies Institute and Department of Oceanography and Coastal Sciences,,Louisiana State University,,Baton Rouge,,LA, 70803**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The objectives of this study are: to measure rates and depths over which macroinvertebrates in selected functional groups transport sediment and create sedimentary structure; and, to derive quantitative mechanistic models for these property distributions. These observations and models will be integrated into mass-transport modeling of dissolved and particulate materials in marine sediments developed under this program. This work is a collaborative effort among Dr. Samuel Bentley (Louisiana State University), Dr. Carla Koretsky (Western Michigan University) and Dr. Yoko Furukawa (Naval Research Laboratory), originally started in 1997 under ONR322GG funding. We will focus on the synthesis of results during this phase. This report summarizes the research activities of Dr. Bentley at LSU.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

WORK COMPLETED

Laboratory data collection. Rates, depths, and styles of bioturbation for two key bioturbators (brittlestar *Hemipholis elongata*, and hemichordate *Schizocardium* sp.) in northern Gulf of Mexico estuaries have been estimated using both direct measurement and deliberate tracer techniques in benthic mesocosms. Experiments with other regionally important macrofaunal species are under way, using ^{134}Cs as a deliberate tracer in microcosm sediments.

Field data collection. Benthic macrofaunal distributions and quasi-steady-state community bioturbation rates (via ^{234}Th, ^{7}Be, and ^{210}Pb tracer techniques) have been characterized for stations in Mississippi Sound and the Louisiana Chenier Plain.

Particle dynamics modeling. Non-steady state particle mixing models for both biodiffusive and bioadvective mixing styles (*Hemipholis* and *Schizocardium*, respectively) have been developed in order to evaluate results of benthic microcosm experiments. The influence of particle mixing by the above macrofauna on fine-scale stratigraphy (e.g., storm beds and other potential acoustic reflectors in the shallow seabed) has been assessed through core analysis (Bentley et al., 2000; Bentley et al., 2001) and numerical modeling of sediment transport, deposition, and bioturbation (Bentley et al., 2001; Keen et al., 2001).

RESULTS

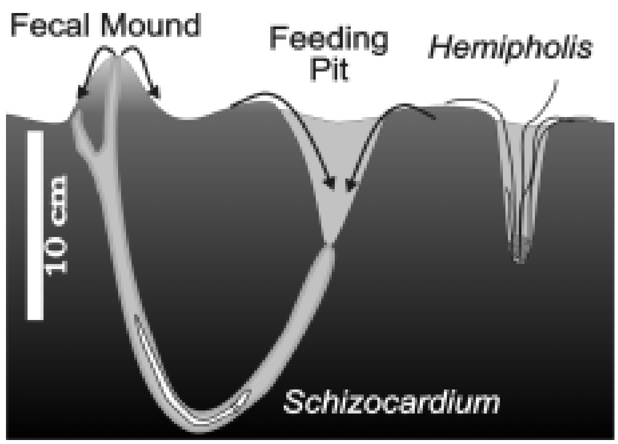

Figure 1. Typical geometry of Schizocardium and Hemipholis burrows. Schizocardium ingests sediment at depth, and egests sediment to the fecal mound as puffs of mucous-laden flocs, with no pelletization or coiled structure. Hemipholis arms are frequently extended into the water column, evidently searching for food particles, but are also seen sifting through surficial sediment. Scale is approximate.

We have identified and quantified the mode and rate of bioturbation for two key species of invertebrate macrofauna (*Hemipholis* and *Schizocardium)* that are similar to other species found worldwide in coastal settings (Fig.1). This was a key element of our initial proposal. We have also adapted particle transport models to describe quantitatively the bioturbation produced by these species.

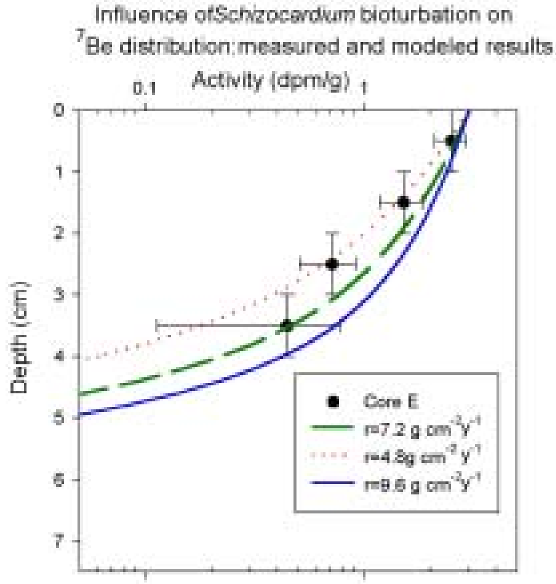

Figure 2. Comparison of ^{7}Be profile in field core E and modeled ^{7}Be profile, assuming that field populations of Schizocardium are ingesting sediment at the same depth and rate as observed in lab mesocosms, using the bioadvection model of Rice (1986). Feeding rate estimates (legend) represent spatially averaged feeding rate for the observed population density (based on lab results), and depict the mean ± 1 standard deviation.

The feeding activity of *Schizocardium* results in bioadvective particle transport to the sediment surface from 5-7 cm below the sediment water interface. A comparison between direct laboratory measurements of particle egestion, and ^{7}Be profiles from field cores (collected at the same station where *Schizocardium* were collected for lab experiments) shows close correspondence between the two sets of observations. Such a correspondence indicates that our lab results are not skewed, and that bioturbation by *Schizocardium* probably controls radiotracer distribution in the shallow seabed of our collection locale (Fig. 2).

Bioturbation by *Hemipholis* is being studied by deliberate ^{134}Cs tracer in lab microcosms, and appears to be diffusive in style. We estimate a biodiffusion coefficient (D_b) of 10 cm^2 y^{-1} over the upper ~7 cm of the seabed from the preliminary data set (spatially averaged at field densities), based on application of a time-dependent diffusion-reaction model. These results are consistent with quasi-steady state profiles of radionuclides measured in field cores.

IMPACT/APPLICATIONS

The continued development of RT models to incorporate biologically created temporal and spatial heterogeneity will allow us to:

(1) predict the course of sedimentary structure evolution for the purpose of sediment stability, acoustic, mine burial, and permeability modeling;

(2) predict the mobility and bioavailability of contaminants following pollution events, dredging, engineering projects, remediation projects, or normal sedimentation for the purpose of site evaluation and planning.

(3) determine the parameters necessary for the particle suspension component of the coastal water optics model (e.g., shear strength of bioturbated seabed and organic carbon content of fluid mud and suspended sediments; Keen and Stavn, 1999) for the streamlined interpretation of optical signals from coastal waters.

TRANSITIONS

Models describing burrow formation (or genesis of sediment heterogeneity) and particle mixing (including rates of change at the sediment-water interface) will have direct relevance to studies of object burial and remote sensing of the shallow seafloor. Preliminary models derived from this work are being used by the NRL-SSC Ocean Modeling Group to assess the preservation potential of fine-scale stratigraphy in the coastal ocean (Keen, T., S. J. Bentley, C. A. Blain, and W. C. Vaughan. 2001. The generation and preservation of multiple hurricane beds in the northern Gulf of Mexico. *Marine Geology*, submitted).

RELATED PROJECTS

This is a collaborative effort between Dr. Samuel Bentley (Louisiana State University), Dr. Carla Koretsky (Western Michigan University), and Dr. Yoko Furukawa (Naval Research Laboratory), originally started in 1997 under ONR322GG funding. Physical modeling efforts are also being coordinated with Dr. Tim Keen (NRL-SSC).

REFERENCES

Bentley, S.J., T. R. Keen, C. A. Blain, W. C. Vaughan, and J. Barnes. 2001. The Origin and Preservation of a Major Hurricane Event Bed in the Northern Gulf of Mexico: Hurricane Camille, 1969. *Marine Geology*, submitted.

Keen, T. R. and R. H. Stavn. 1999. Developing a capability to forecast coastal ocean optics: Minerogenic scattering. 6th *International Conference on Estuarine and Coastal Modeling, Proceedings*, 178-193.

Rice, D.L., 1986, Early diagenesis in bioadvective sediments: Relationships between the diagenesis of ^{7}Be, sediment reworking, and the abundance of conveyor-belt deposit feeders: Journal of Marine Research, v. 44, p. 149-184.

PUBLICATIONS

Bentley, S.J., Y. Furukawa, and W. C. Vaughan. 2000. Record of Event Sedimentation in Mississippi Sound. 2000 *Transactions of the Gulf Coast Association of Geological Societies* **50**, 617-625.

Bentley, S.J., T. R. Keen, C. A. Blain, W. C. Vaughan, and J. Barnes. 2001. The Origin and Preservation of a Major Hurricane Event Bed in the Northern Gulf of Mexico: Hurricane Camille, 1969. *Marine Geology*, submitted.

Furukawa, Y., S. J. Bentley, and D. Lavoie. 2001. Bioirrigation modeling in experimental benthic mesocosms. *Journal of Marine Research* **59**, in press.

Keen, T., S. J. Bentley, C. A. Blain, and W. C. Vaughan. 2001. The generation and preservation of multiple hurricane beds in the northern Gulf of Mexico. *Marine Geology*, submitted.